Spectrum Requirements for 4G Wireless Systems

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Outline

- Introduction
- Radio Spectrum Management – Why?
- The ITU framework for spectrum management
- The ITU Vision for the future development of IMT
- ITU Studies related to WRC-07 agenda item 1.4
- Spectrum Requirement Estimation Methodology
- Back to spectrum demand – So how much?
- Candidate bands
- Conclusions

Introduction

- Advent of 4G systems
  - Europe: IST Winner project
  - IEEE 802.16m and 802.11s
  - ITU: IMT-Advanced
- Common vision: “High speed data transmission capability anytime, anywhere”
- Besides all the interesting technical challenges there is one key question to solve:

  Do we have the required radio spectrum?

Radio Spectrum Management – Why?

- Quite soon after the invention of radio at the beginning of 20th century the need for radio spectrum management became evident
  - Uncoordinated growth in number of radio stations
  - There were no rules for transmission power and bandwidth
  - Radio communication became relevant for public safety (e.g., sinking of the *Titanic*)
- Today, the air is full of radio transmissions
- The main problem: Interference
  → Most applications of radio technology only work properly in **dedicated spectrum**
- Conclusion: There is a need to **manage** and to **regulate** radio spectrum usage

Users of Radio Spectrum

- Civil Telecommunications (Fixed, Mobile & Satellite)
- Military communications and radars
- Aeronautical communications and radars
- Maritime communications and radars
- Broadcasting
- Space Science Services
- Radio Astronomy
- Earth Exploration Satellites
- Amateur Radio
- Industrial, Scientific and Medical applications

Spectrum Management – A Local Matter?

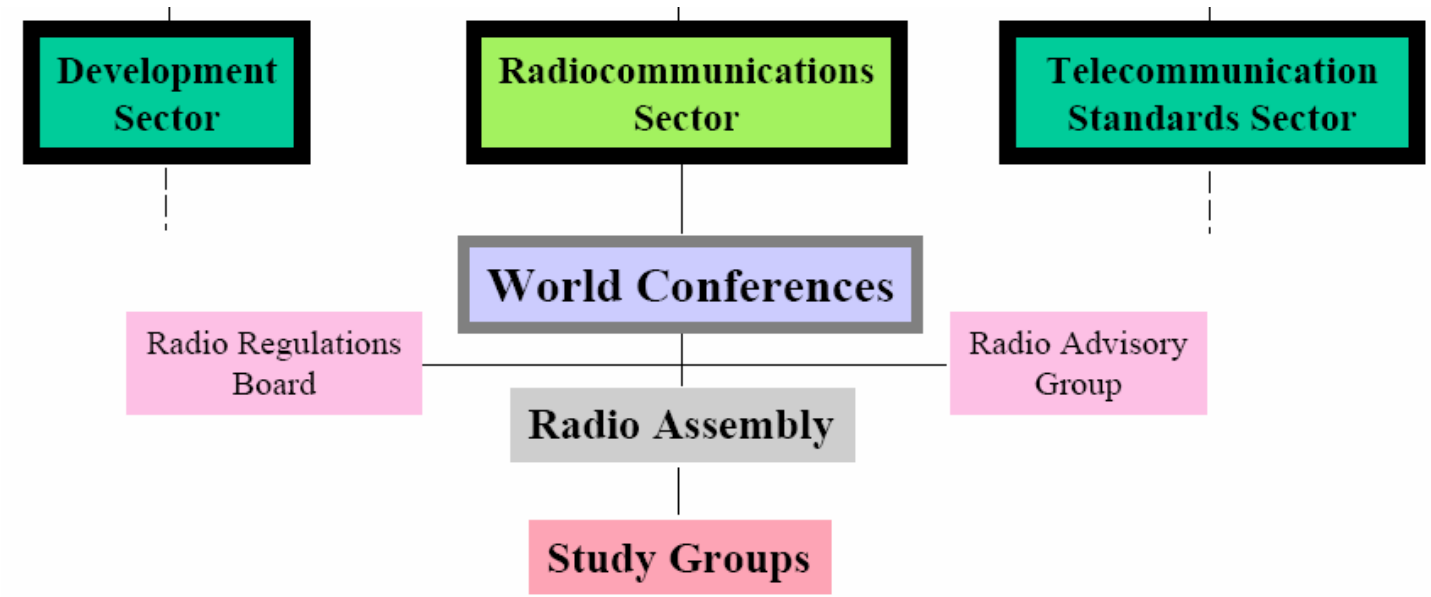
- Ultimately the responsibility for managing frequency usage falls to a National Regulatory Authority (NRA)
  - BNetzA in Germany
  - OfCom in the UK
  - ANFR in France
  - FCC and NTIA in the USA
- NRAs decide:
  - What radio equipment is permitted to be used in each band
  - If, to whom and how a band is to be licensed

- **But:**
  - Radio waves do not respect national borders
  - Using the same frequency range all over the world in many cases is the **key to the success** of a technology

→ **Spectrum management on national level only is not sufficient, international coordination is a must!**

The ITU Framework for International Spectrum Management

- An international organization within the United Nations system
- Responsible for Telecommunication matters in general
- With respect to radio spectrum usage, ITU is responsible for global regulation and management for **all** radio spectrum users (also non-communication services)



The ITU Radio Regulations

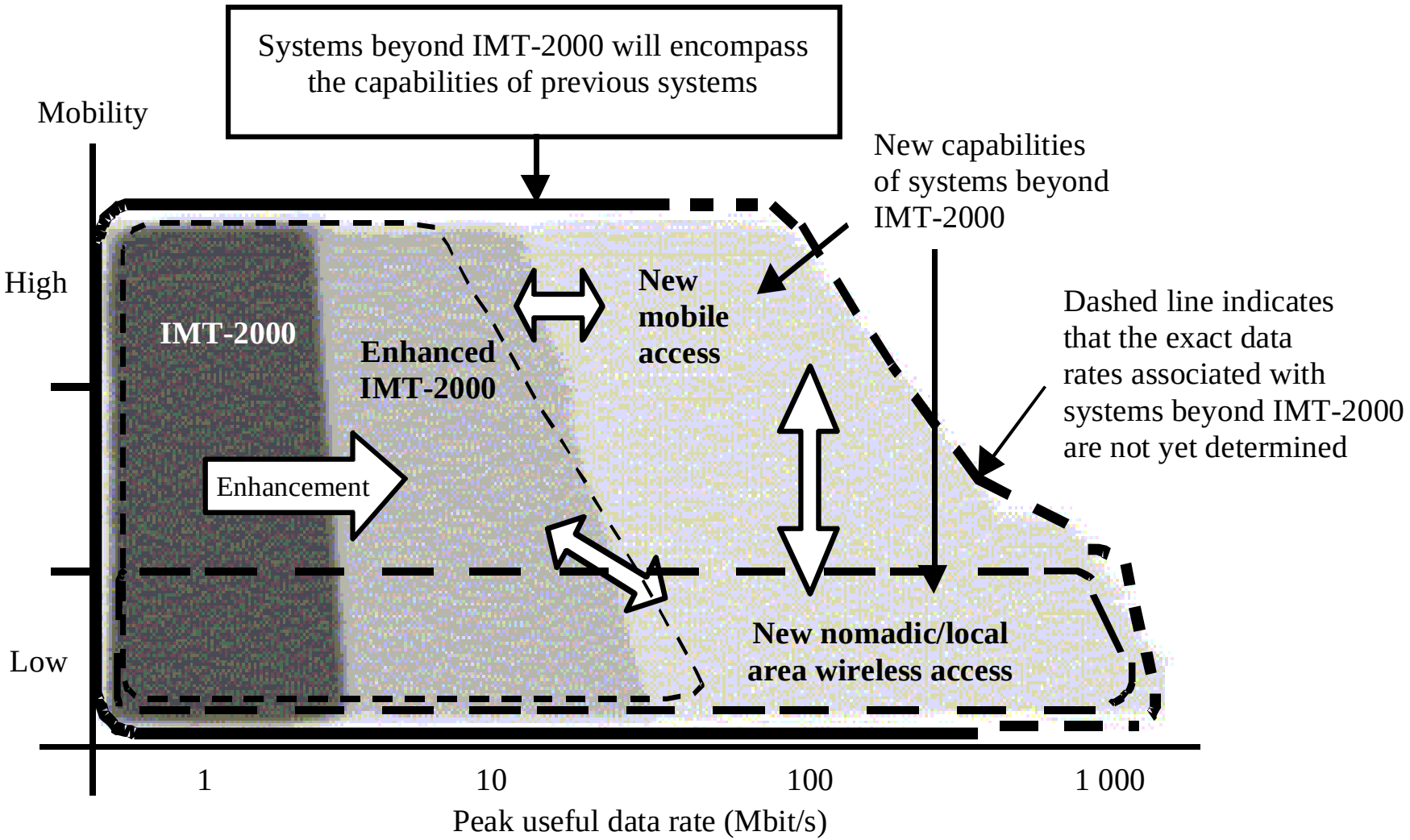
- For regulating and managing radio spectrum usage, the ITU-R **"Radio Regulations"** have been developed
- The RR
  - are recognized as an International Treaty
  - set a framework for National Regulatory Authorities to license radio spectrum usage

- They contain
  - Tables of frequency allocations
  - Definition of services (e.g. Fixed, Mobile, Satellite, Radiolocation, etc.)
  - Technical constraints as required on international level (e.g. emitted power limits)
  - Procedures (registration, coordination)

The ITU-R World Radio Conference
- Only Opportunity to Change the RR -

- The only institution that can make changes to the Radio Regs is the **World Radio Conference** (WRC)
- WRCs are held every 3-4 years (the next one is held Oct-Nov 2007 in Geneva, Switzerland)
- The agenda for each WRC is agreed at the previous conference
- The time between WRCs is called **“study period”**
- Studies to undertake are mandated by resolutions of the previous WRC
- Results of the studies are collated into a single Report by the “Conference Preparatory Meeting” (the so-called “CPM Report”)

The ITU Vision for Future Systems: IMT-advanced

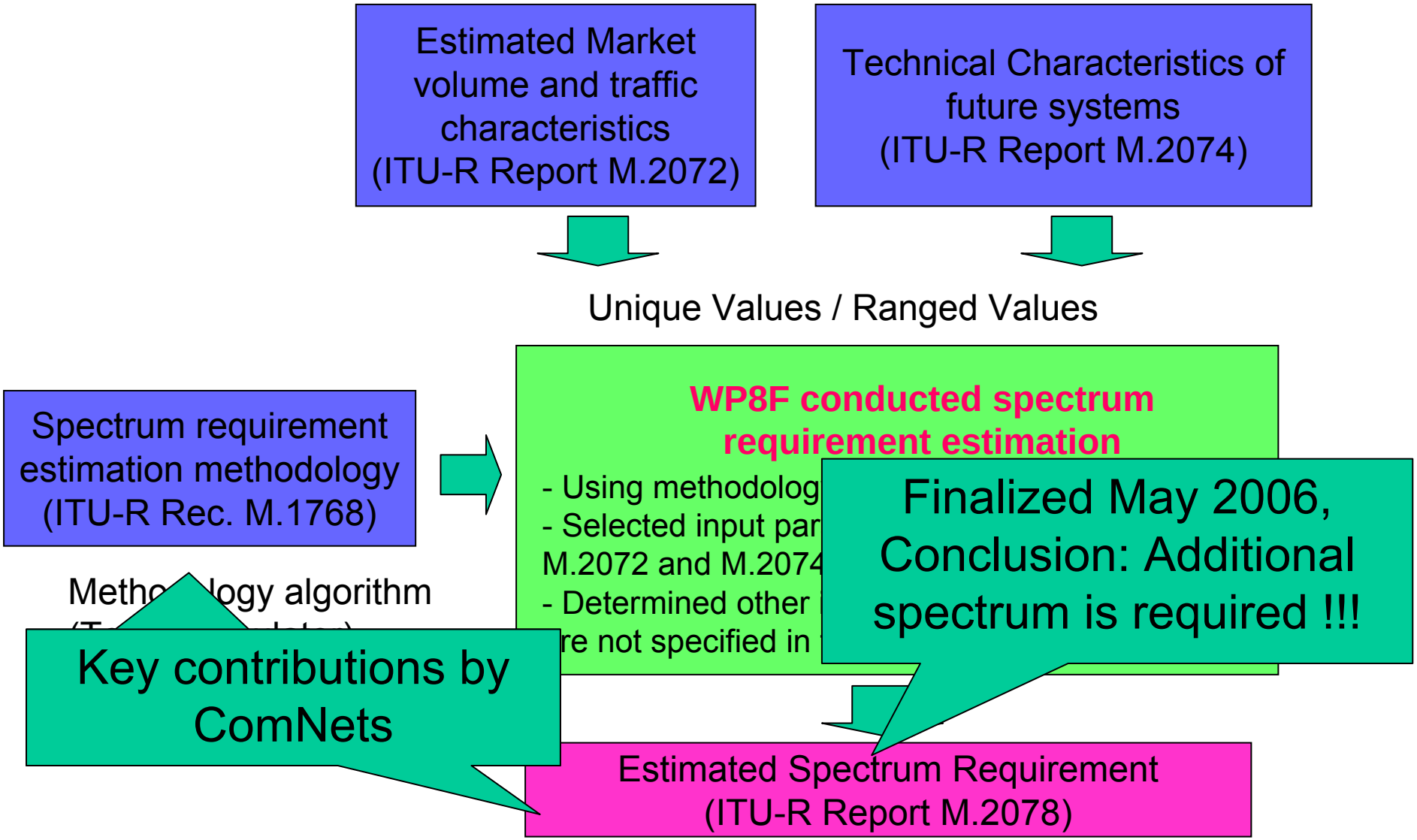


Source: ITU-R Recommendation M.1645

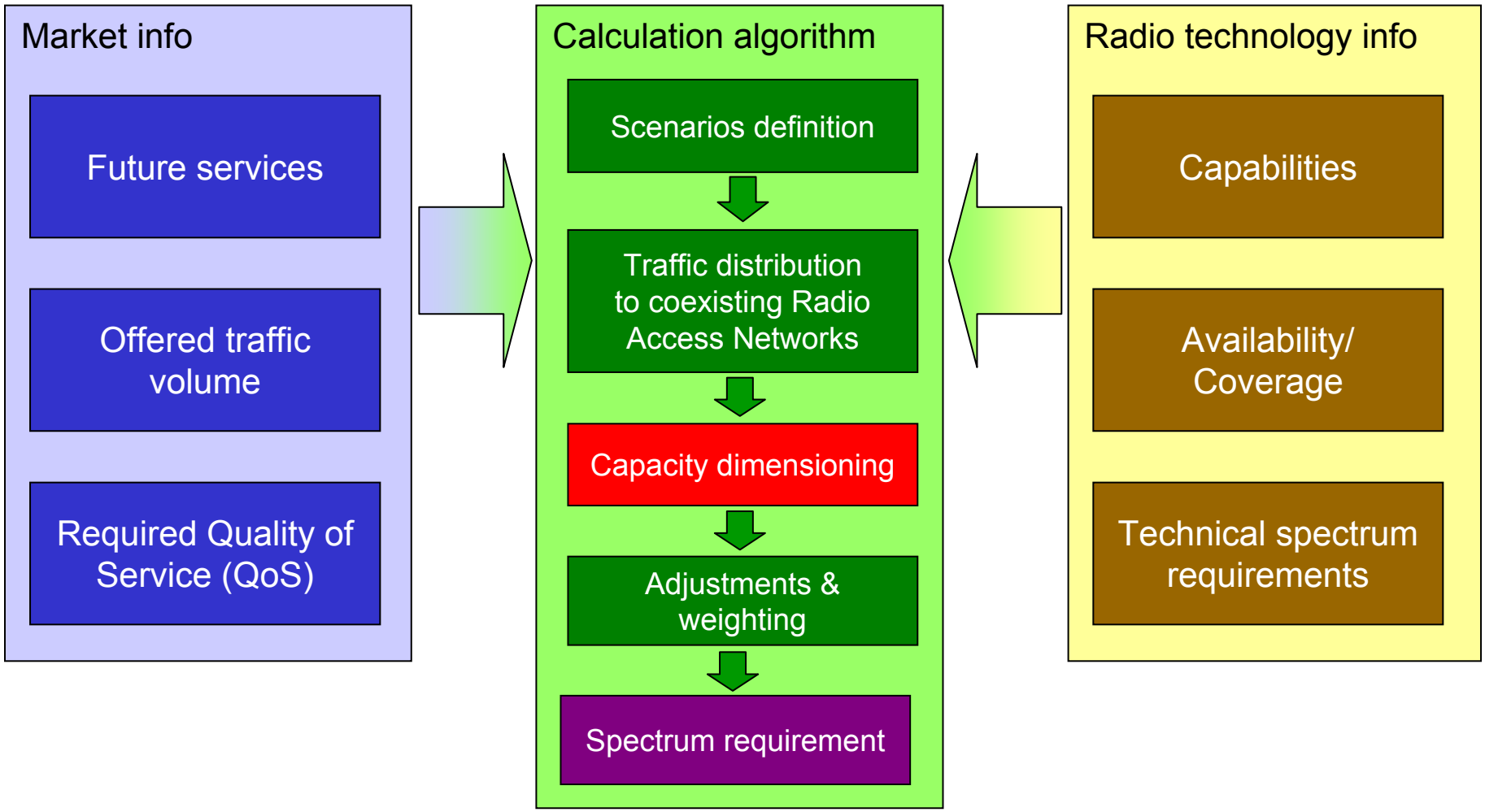
Spectrum Requirement Estimation – Cornerstone of WRC-07 Preparation

- WRC-07 agenda item 1.4:
  „to consider frequency-related matters for the future development of IMT-2000 and IMT-Advanced (systems beyond IMT-2000)“
  (Translation: “See if additional spectrum for IMT is needed and if yes, make appropriate changes to the RR”)
- The spectrum allocation in the Radio Regs does not have “blank spots”
  - Additional spectrum for terrestrial mobile communication requires constraining spectrum availability for other Services
  - Conflicting interests between civil and military users and between civil users from multiple industries
- ITU-R WP8F conducted a study on spectrum requirement for systems beyond IMT-2000 in the scope of WRC-07 preparation

WP8F Spectrum Requirement Estimation Process

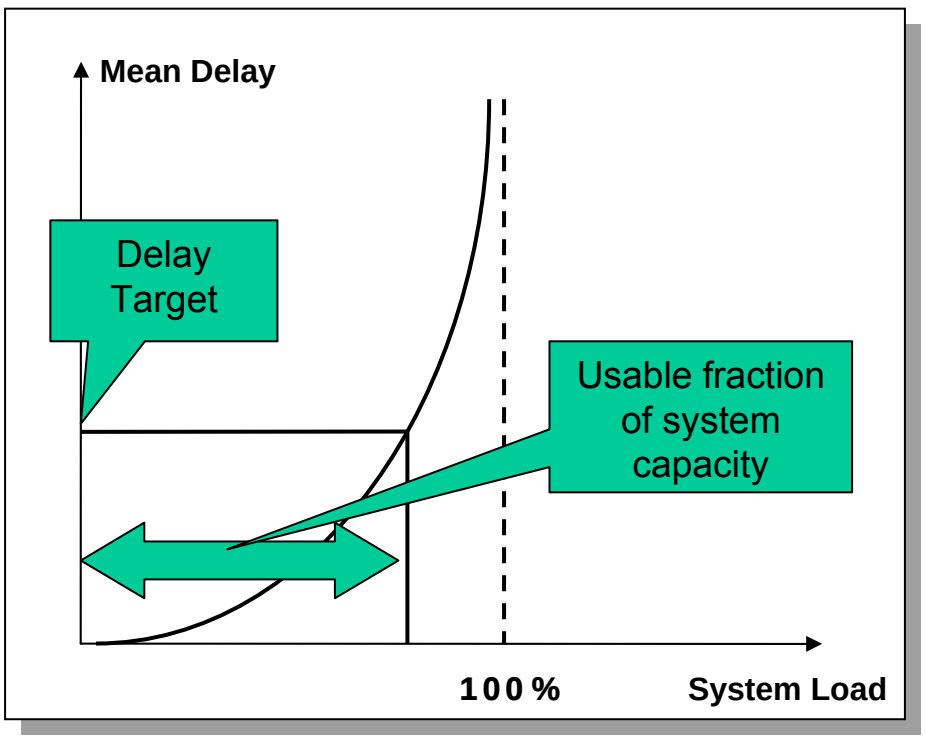


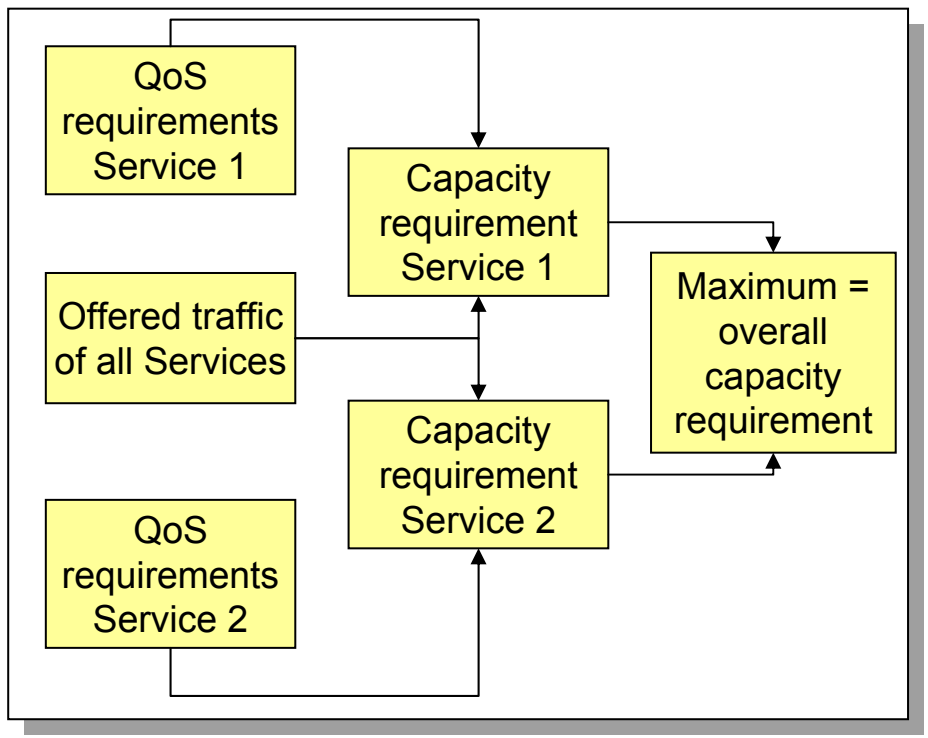
Spectrum Requirement Estimation Methodology Overview



Required System Capacity: General Approach

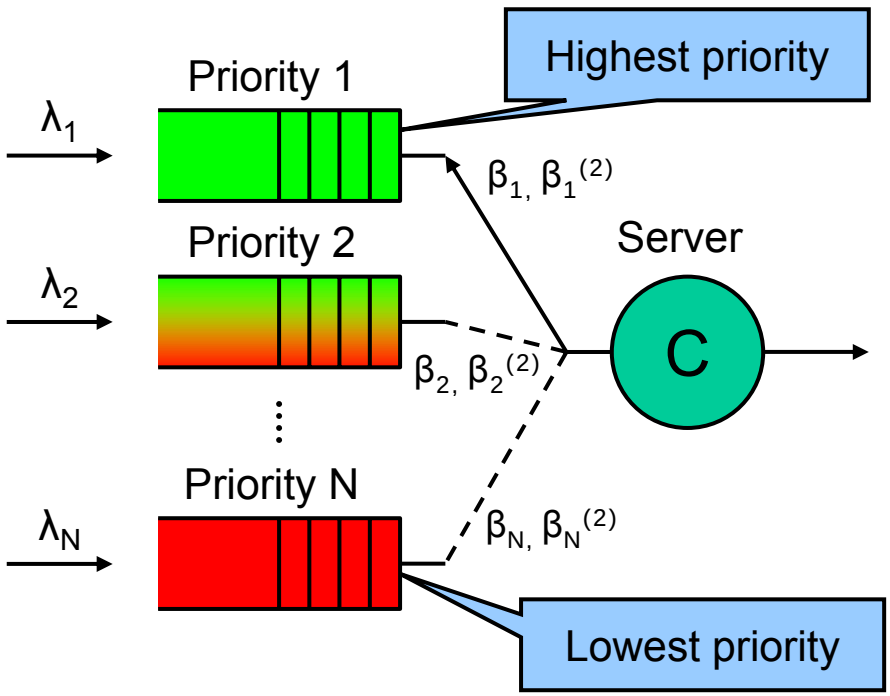
- Problem to solve: Calculate required system capacity under given QoS constraints
- Widely known: QoS constraints require certain amount of free capacity → Required capacity is a function of offered traffic volume, traffic characteristics and QoS requirements





Required System Capacity: Queuing Model

- Calculate required system capacity using M/G/1-FCFS queue with non-preemptive priorities ("head-of-the-line priorities")
- Throughput requirements met by operating queue in stable state
- Delay requirements need properly dimensioned capacity C

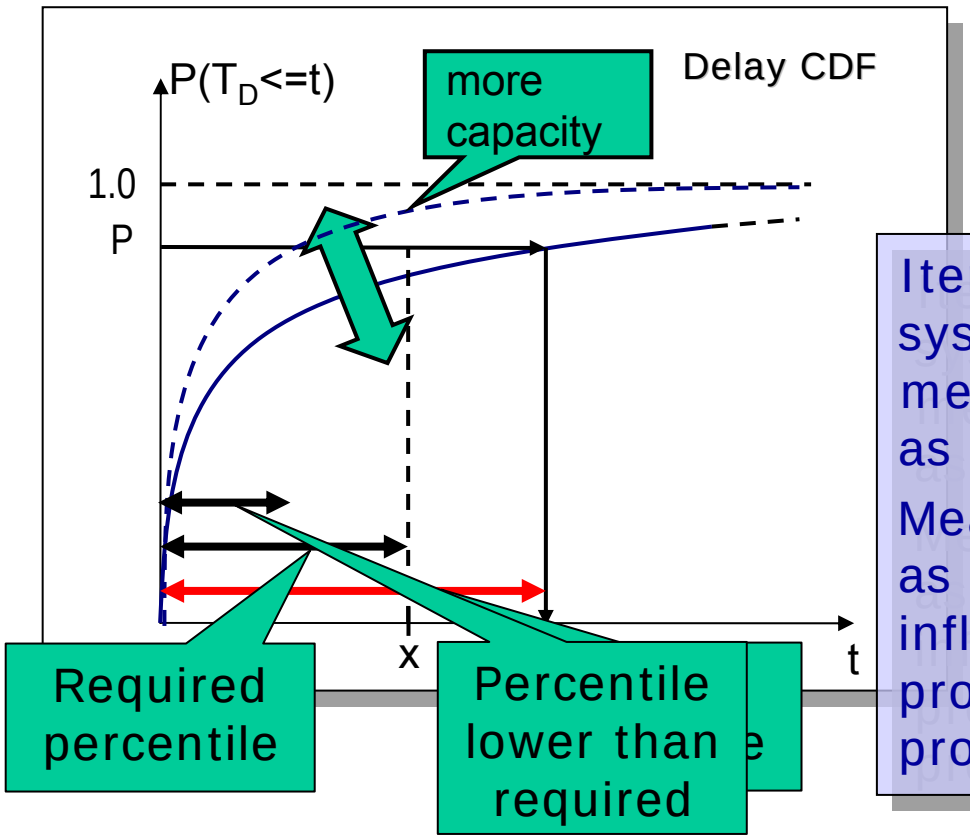


Parameters of the model:

- λ_i : arrival rate of packets with priority i
- β_i : mean service duration of packets with priority i
- $\beta_i^{(2)}$: second moment of service duration
- D_i : required mean delay

Required System Capacity: Delay Percentiles as QoS Criterion

- Required delay performance usually additionally specified in terms of percentiles (e.g. (E)GPRS and UMTS QoS classes)
- Required delay percentile: *P* % of all packets must be served faster than or equal to x seconds (usually 95% percentile is considered)



- Determine delay *Cumulative Distribution Function* (CDF) under capacity calculated to meet req. mean delay

Iterative approach, using system capacity calculated to meet mean delay requirement as input

Mean delay can be considered as a starting point selection that influences convergence properties of the iterative procedure

Back to Spectrum Demand - So how much?

- Results of ITU spectrum requirement estimation study
  - Low user demand: 1280 MHz required in year 2020
  - High user demand: 1720 MHz required in year 2020
  - For comparison: in Europe, currently 585 MHz are available
- Where to find it?
  - Main IMT-Advanced candidate bands: 3400–4200 and 4400-5000 MHz
  - Only candidate bands that provides sufficient amount of spectrum
  - Heavily opposed by FSS community
  - Current FSS usage is under-utilizing the band, re-organization of FSS deployments would permit use by mobile systems in parallel

Conclusions

- Spectrum management consists of a complex mixture of technical, regulatory, commercial and political considerations
- The common vision of the wireless industry foresees availability of very high data rate always and everywhere
  → To turn this vision into reality (and of course into commercial success, too), additional radio spectrum is needed
- For having additional spectrum available in time, WRC-07 is the only chance to make the required changes to the international frequency usage plan
- The relevant WRC input documents clearly state the need for additional spectrum, and the credibility of these estimations is undisputed
- **Chances for getting additional spectrum identified at WRC-07 are as good as they can be**
- **ComNets made key contributions to the process**

Thank you!

Questions welcome…

…now or later…

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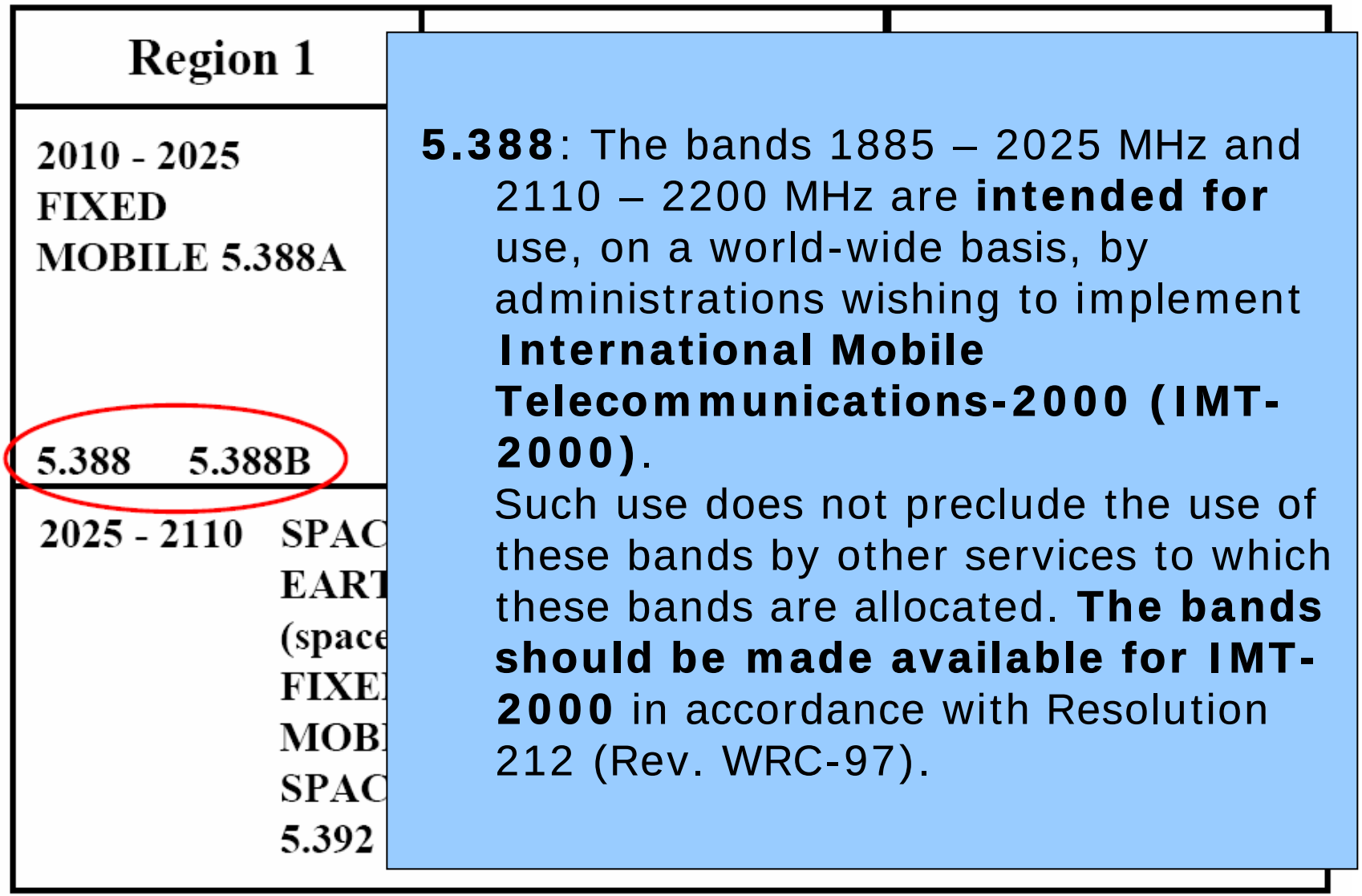
Backup

Radio Regs Article 5 - Example

Region 1	Region 2	Region 3
2010 - 2025 FIXED MOBILE 5.388A	2010 - 2025 FIXED MOBILE 5.388A MOBILE-SATELLITE	2010 - 2025 FIXED MOBILE 5.388A

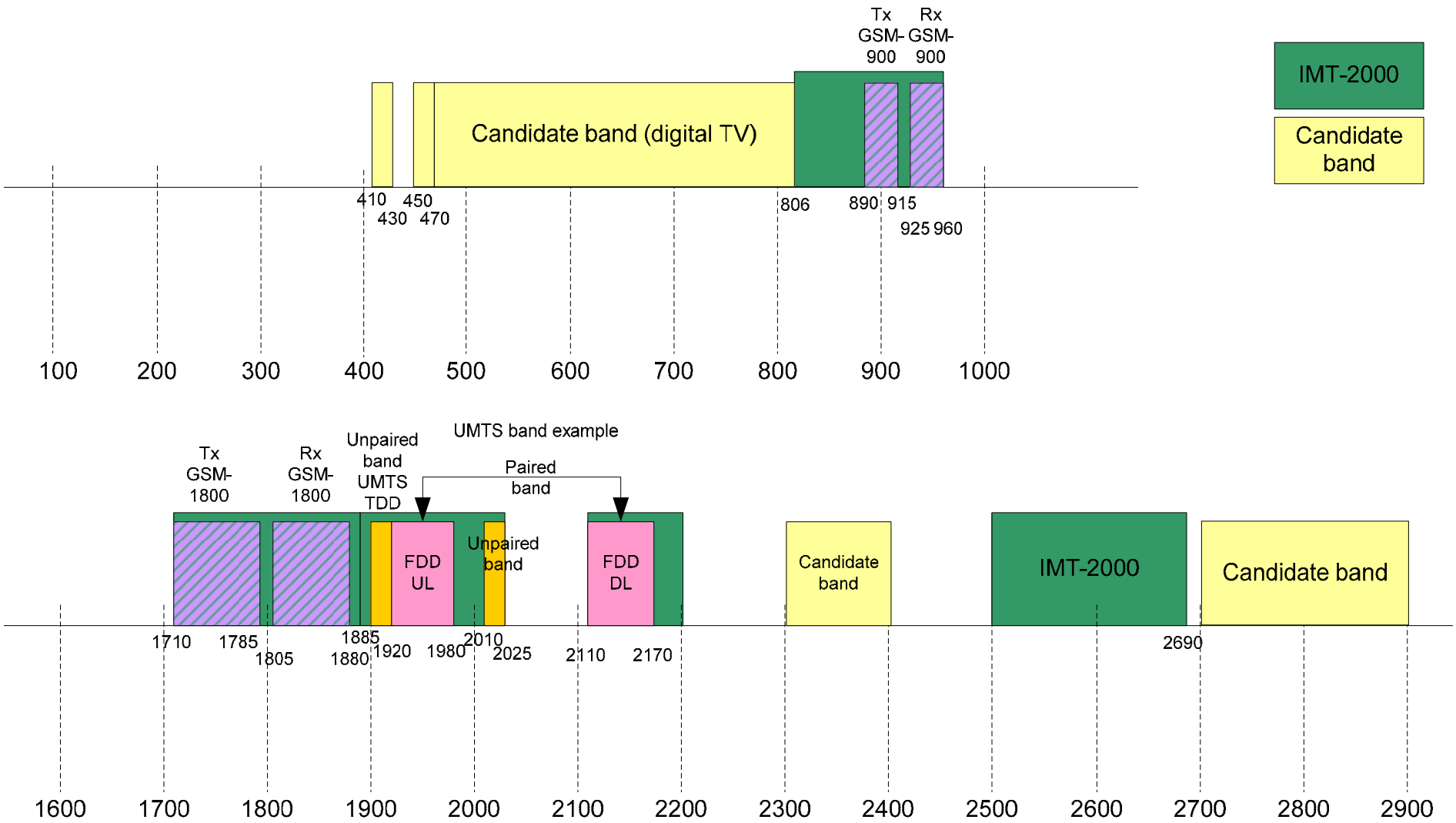
- Each frequency band can be allocated to several different **Services**
- Primary allocations are written in capitals
- There can be co-primary allocations
- Each NRA can choose which Services to license
- The Services in one band are selected so that there is a certain degree of compatibility (i.e., they can be coordinated, etc.)

Radio Regs Article 5 - Example



5.388: The bands 1885 – 2025 MHz and 2110 – 2200 MHz are **intended for** use, on a world-wide basis, by administrations wishing to implement **International Mobile Telecommunications-2000 (IMT-2000)**.
Such use does not preclude the use of these bands by other services to which these bands are allocated. **The bands should be made available for IMT-2000** in accordance with Resolution 212 (Rev. WRC-97).

Candidate Bands



Candidate Bands